ARKIV FÖR FYSIK Band 11 nr 46

Communicated 28 November 1956 by George de Hevesy and Harald Norinder

Conduction of electricity through ice and snow

III. Current through snow and distribution of potential in a snow sandwich

By Reinhards Siksna and Arvids Metnieks

With 10 figures in the text

After the first measurements of the electrical resistivity and conductivity of ice crystals had been finished [1, 2] the question arose: What behaviour have the same properties for snow?

1. Preliminary recording of the current through snow

A cylindric vessel of paraffined paste-board was taken for the first preliminary measurements. Two well-insulated brass plates (4.4 × 4.6 cm) were put into the vessel at 3.2 cm distance from each other and connected to the device used earlier for recording of the current through ice crystals [2]. Then snow was poured into the vessel at light shuttering until it completely covered the two plates. The current curves recorded through snow (Fig. 1, both upper curves) had a form similar to the curves obtained with ice [2]. Some difficulties were encountered, especially at higher temperatures (some centrigrades under zero): contact between snow and the plates gradually became worse, to cease altogether when the snow round the plates had thawed or sublimed. For the next experiments (Fig. 1, lower curve) a new holder was therefore developed, as shown in Fig. 2 (upper right corner). Two obliquely bent stripes of brass plate were fastened on a plexiglass plate, being at the same time holders of snow and electrodes. As can be seen (Fig. 1, lower curve) the trend of the current in this device is similar to those before. But even with such an arrangement, when having temperatures near 0°C, snow contact with the electrodes was broken, particularly when the device had been left unused for some time. Nevertheless we have recorded some unspoiled current curves in the temperature range $-3.5°C \rightarrow -23.5°C$ (Fig. 2) and they are very much like those obtained for ice crystals [2]: after a short increase the current decreases again and tends to attain some definite level which is always lower than that at the beginning.

It seems that the preliminary experiments proved that the currents for snow and ice are essentially similar. Therefore it may be assumed that in general (not in details) the electrical processes in snow and ice can well be similar. Thus it seemed that there

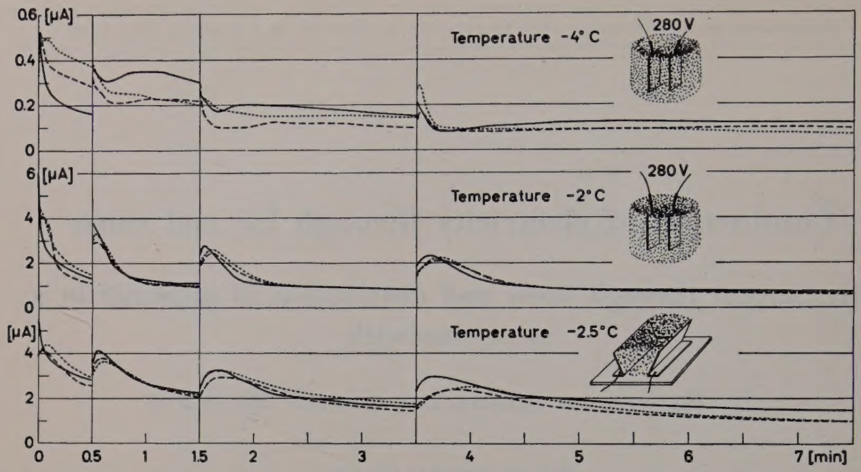

Fig. 1. Current through snow by using two rectangular electrodes (two top curves) and by using brass stripes on plexiglass (bottom).

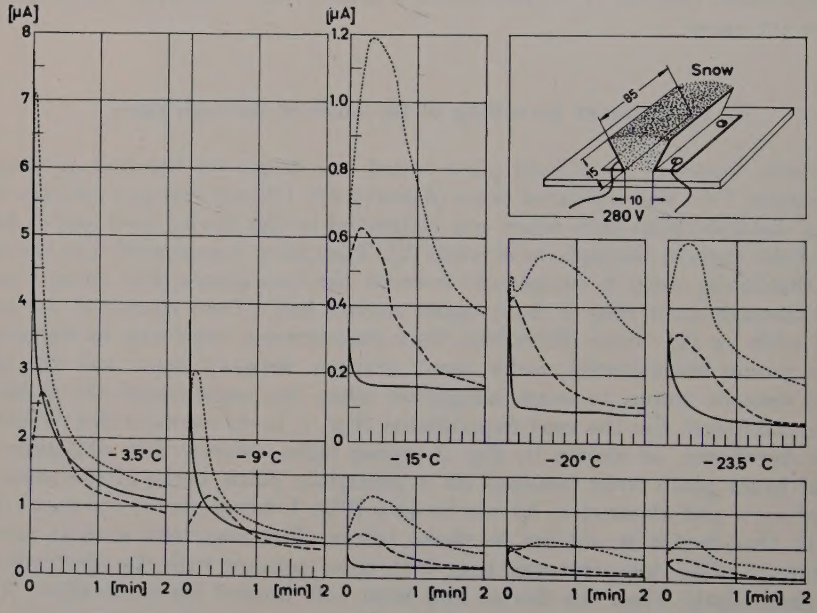

Fig. 2. Current through snow in dependence on decreasing temperature.

were new possibilities of investigation of these processes: it is much easier to make a homogeneous snow sandwich with some inserted sieves as sounds between the end electrodes than would be a similar sandwich from ice. For the following experiments, therefore, such a snow sandwich was used.

2. Distribution of the potential in a snow sandwich

2.1. *Experimental.*—A sandwich of snow was made: 4 brass-sieve electrodes (12 cm ∅) with three pressed snow discs 1.2 cm thick inserted between them. The first sandwich used was made of fine ungranulated snow (which had not thawed). The four electrodes were connected to 4 high quality cables leading out from the cold-box and then connected in different combinations to a bifilar Wulf electrometer. A potential of 180 volts was applied to the outward electrodes of the sandwich and the distribution of the potential between the individual sections was measured and also how this distribution changes with time. Potentials between the electrodes of the partial sections were measured one after another in the sequence shown in the following figures; it would be more correct to measure them simultaneously.

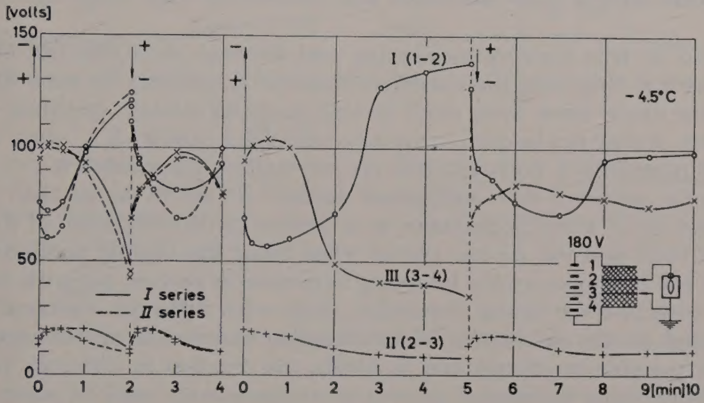

Fig. 3. Time variations of the potential distribution in three sections of a snow sandwich.

2.2. *Results.*—Results of the measurements for the first sandwich with the slightly pressed but slack snow are shown in Fig. 3. In this case initially most of the potential fell on the outside sections of the sandwich, (1–2) and (3–4), the inner section (2–3) having only a minute part of the whole tension. It is evident that in this case the initial distribution of the potential was quite accidental as it is impossible to make several snow discs exactly similar and with the same qualities. After switching on the tension already during the first two minutes a rearranging of the potential distribution occurred: the potential drop increased in the section (1–2), decreased in the section (3–4), but in the middle section the change was small during the whole series; the amplitude of the changes in this section was smaller than in the two outside sections. Thus this was one of the rare cases when the dropping of the potential in the section (2–3) remained nearly constant and the end sections changed their potential distribution one on the others' account. In most cases one end changed its potential on the account of the middle section, the potential dropping in the other end section (the one with the smaller tension) remaining nearly unchanged. After commutation of the polarity during the following two minutes some rearranging of the potential distribution was observed. Then the 2 + 2 minutes' series were repeated (dashed curves) and the curves of both series agreed very well (I and II series). After finishing these series it seemed that when the sandwich was under tension of one polarity for only two minutes no lasting state could be attained. Therefore during the following series the potential of each direction was held on for 5 minutes. As shown in the figure, during the first 5 minutes most of the tension applied was gradually arranged on the section (1–2). After commuting the polarity, a rearranging of the potential distribution occurred; yet the section (3–4) did not receive most of the tension, as could be expected. Obviously there was no hope of obtaining reproducible results with the sandwich used, especially when measurements were continued for a long time—the snow at the electrodes disappeared by thawing and sublimation and the contact was broken. Therefore it was tried to make sandwiches with more constant qualities by thorough moistening of the snow sandwiches with water and by freezing.

3. Experiments with a snow sandwich first moistened with water and then frozen

It proved to be true that by moistening and freezing snow one can obtain more usable sandwiches: they were more solid mechanically, contacts between the electrode sieves and the snow discs were more lasting and the electric qualities were more constant. True, it may not be quite correct to call such a sandwich a "snow sandwich", for it rather resembles a homogeneous polycrystalline ice sandwich.

3.1. *Snow-ice sandwich as a methodical means.*—It seems to us that a snow-ice sandwich may be of some importance as a device for investigation of the electrical properties of snow and ice. As was shown when using the slightly pressed snow sandwich, and as will be shown by the following experiments carried out with the snow-ice sandwiches with inserted sound electrodes, spots with different electrical properties can be located in the sandwich. When changing the electrical field applied or its polarity it is possible to change and to locate the changes in different parts of the sandwich. When using moistened snow it is comparatively easy to assemble such a sandwich. Obviously, it will be of importance to insert the sounds also in a single ice crystal, but technically such an operation is not very easy. However, with the moistened snow we succeeded in building mechanically rigid sandwiches with comparatively constant electrical properties.

3.2. *General properties.*—In general the moistened and thereafter frozen snow-ice sandwich showed qualities very similar to those of loosely poured snow. The only remarkable difference was that the changes caused by the applied field were slower. In the case of the snow sandwich, as shown in Fig. 3, a somewhat stationary state was reached after applying the electric field in one direction for 3–5 minutes. When using the snow-ice sandwich, a state of some balance was attained only after about 10 minutes (Fig. 4). However, the qualities of the snow-ice sandwich were much more reproducible, as can be seen from the two consecutively repeated series (I) and (II).

3.3. *Dependence on temperature.* Because of a better definition of the properties of the snow-ice sandwich it seemed to be possible to investigate the change of the potential distribution with time in dependence on the temperature. Results of such series are shown in Figs 4–7 and they can be summarized as follows:

(1) The change of the potential drop in a particular section was larger at a higher temperature (near 0°C) and smaller at a lower temperature (the lowest temperature used by us was -23°C).

(2) The time for reaching a definite state after commutation of the polarity was shorter at a higher temperature (-5°C) and increased at a lower temperature.

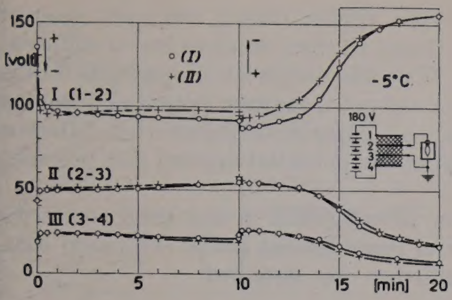

Fig. 4.

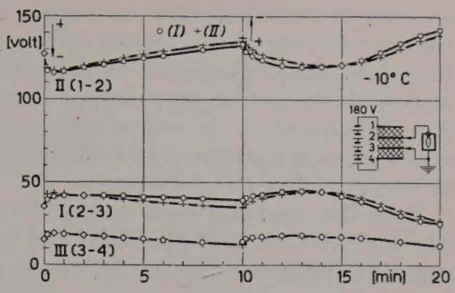

Fig. 5.

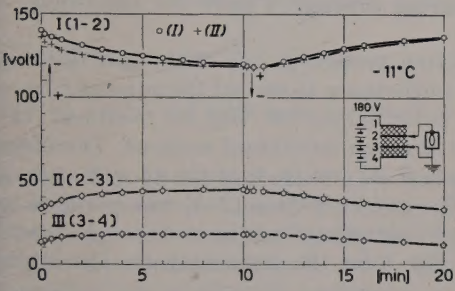

Fig. 6.

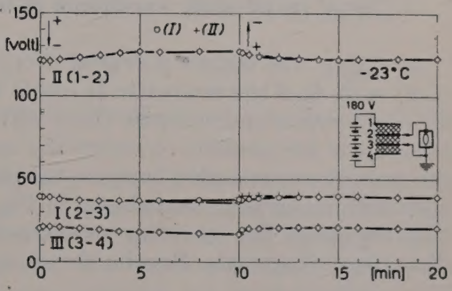

Fig. 7.

Figs. 4–7. Time variations of the potential distribution in three sections of the large snow-ice sandwich.

(3) It seems that the levels reached after the change of polarity are almost independent of the temperature at which the measurement was made, only the time period required to reach the level being different.

(4) Keeping under tension for some hours or even some days diminished the amplitude of the changes of the potential. We shall return to these phenomena in the following section.

(5) Lower temperatures diminished the amplitude of the potential changes as well.

4. Some experiments with a small snow-ice sandwich

The sandwich described in the previous section was unsuitable for current measurements because the current was too great for our current recording device [2]. Therefore a small snow-ice sandwich was made having four 38 mm ⌀ brass sieves as electrodes and with 1 cm thick snow layers between them. This small snow-ice sandwich did not show an equally good regularity as the previous one when repeating the measurements, possibly because the snow used was older and granulated. In general, however, its properties were similar to those shown by the previous sandwich. A curious behaviour of this small sandwich was observed: initially most of the potential was present in the upper (1–2) section, after one night at a tension of 180 volts it shifted to the lower (3–4) section and remained there for some series irrespective of the changing of the polarity and of other treatment, and at last after a repeated treatment with the tension of 180 volts applied during one night most of the potential was in the middle section (2–3). Thus, all three sections had at different times had the greatest part of the potential. With the sandwich in question it was impossible to control the potential distribution and get the largest potential dropping in a desired section. As will be shown in a following paper with a somewhat different sandwich such a controlling of the distribution of the potential applied was possible, at least regarding the end sections.

With the sandwich used during the present investigation it was tried to clarify whether common light (day-light and light from incandescent lamps compared with complete darkness) has any influence. No influence was detected.

5. Some small-scale variations of the current through a snow-ice sandwich

As shown, the largest potential drop was often present in one of the end sections (1–2) or (3–4) of the sandwich. It would be of importance to record the current curves for each section and compare them with the potential curves. But for technical reasons it was not possible to record the current through individual sections. Therefore the current was recorded between the terminals (1–3) and (2–4) of the snow-ice sandwich with an arrangement shown in Fig. 8. The middle section (2–3) was common in both the cases. The recording was carried out by commutating the sections (1–3) and (2–4) every 5 seconds. Results are shown in Fig. 9 for the large snow-ice sandwich,

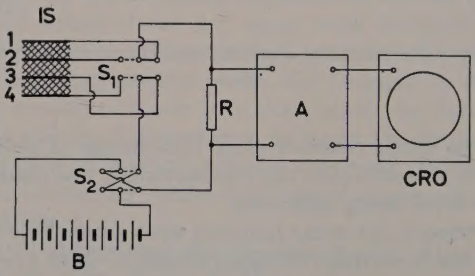

Fig. 8. Schematic diagram of the arrangement for current recording through snow-ice sandwich *IS*. S_1, switch for commutating the sections (1–3) and (2–4); S_2, switch for commutating the polarity of the battery *B*; *R*, current resistor; *A*, amplifier; *CRO*, cathode-ray oscillograph.

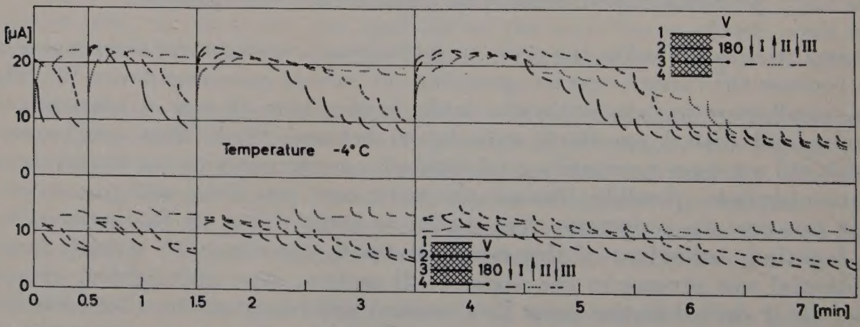

Fig. 9. Large- and small-scale variations of the current through the large snow-ice sandwich.

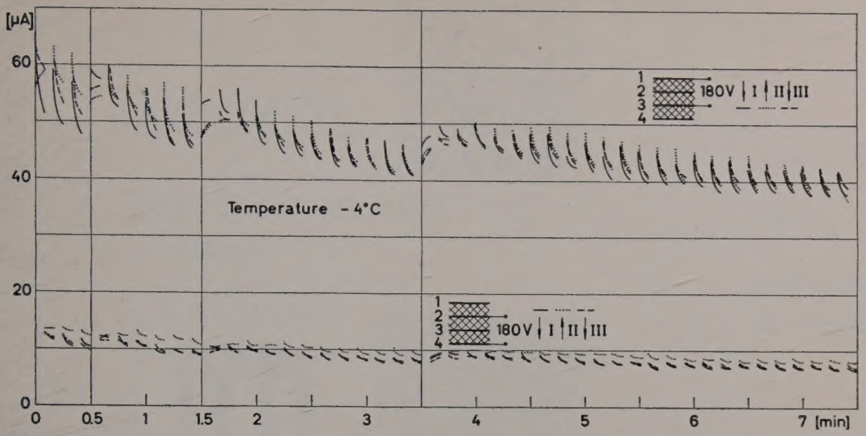

Fig. 10. Large- and small-scale variations of the current through the small snow-ice sandwich.

and in Fig. 10 for the small one. Besides the large current variations which are in general similar to those of the current through single ice crystals [2], small-scale time variations were observed during the separate 5-second intervals; for the large sandwhich these variations were particularly marked. We will not go into details here regarding the small-scale variations, as our main intention was to show that in the snow-ice sandwich the large-scale variations were similar to those of the single ice crystal. However, Figs. 9 and 10 will show that behind the large-scale variations we should not disregard those of a small scale. If they are essential it is of importance to investigate them in greater details, and even if they are only caused by some induction effects in the device used, it is not less important to know their nature in order to avoid false interpretation.

ACKNOWLEDGEMENTS

The authors are grateful to the Director of the Institute of High Tension Research of the University of Uppsala, Professor H. Norinder, for providing them with facilities to carry out this work and for his interest in its progress. Thanks are due to the Swedish Natural Science Research Council for placing means at the disposal of the Institute to perform this work.

Institute of High Tension Research, University of Uppsala, August 1956.

REFERENCES

1. Siksna, R., Conduction of electricity through ice and snow. I. *Arkiv fys.*, *11*, Nr 43, 495–510 (1957).
2. —— Conduction of electricity through ice and snow. II. *Arkiv fys.*, *11*, Nr 44, 511–528 (1957).

Tryckt den 14 mars 1957

Uppsala 1957. Almqvist & Wiksells Boktryckeri AB